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6 FORMULATION OF A MODEL TO PREDICT SECOND DESTINATION TRANSPORTATION TONNAGE ESTIMATES FOR FUTURE BUDGET REQUIREMENTS.

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The purpose of the research was to develop a better method for computing SDT tonnage estimates which are used to derive future budget requirements. The objectives were to determine whether flying hours, manpower, or both were significantly reliable predictors of tonnage estimates and to develop a computerized model for computation of SDT tonnage and budget estimates. Obtaining both actual and programmed data with MAC as a data source, discontinuous linear regression was used to derive twelve equations for the five overseas geographic areas serviced by MAC. The equations were synthesized into four models which were tested by various statistical methods to determine their overall validity. The optimal model chosen verified that programmed flying hours and manpower were significantly reliable predictors of tonnage estimates. A comparison between the optimal model and the method currently used to estimate tonnage revealed that the model provided a significantly more accurate estimation of tonnage to be moved. Computerization of the model was developed utilizing FORTRAN and the Statistical Package for the Social Sciences. After reviewing the results, the authors concluded that tonnage can be estimated using programmed flying hours and manpower as variables to derive future SDT budget requirements.

LSSR 21-78B

# FORMULATION OF A MODEL TO PREDICT SECOND DESTINATION TRANSPORTATION TONNAGE ESTIMATES FOR FUTURE BUDGET REQUIREMENTS

A Thesis

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Logistics Management

By

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September 1978

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This thesis, written by

Captain Christopher J. Lamb

and

Captain Joseph B. Sarnacki

has been accepted by the undersigned on behalf of the faculty of the School of Systems and Logistics in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN LOGISTICS MANAGEMENT

DATE: 8 September 1978

Paul J. Tully

COMMITTEE CHAIRMAN

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# CHAPTER I

# INTRODUCTION

Currently, determination of future Second Destination Transportation (SDT) general cargo tonnage requirements for the Military Airlift Command are being computed manually, utilizing historical and programmed flying hours and previous tonnage transported as predictors. The intent of this study is to develop a method for computing tonnage estimates to derive future SDT budget forecasts.

## Statement of the Problem

A validated method does not exist for computation of tonnage estimates to derive future SDT budget requirements.

## Background

"Second Destination Transportation is frequently referred to as all transportation which is not first destination [14:3]." Each is defined as:

> First Destination Transportation: (1) the movement of property from f.o.b.[1] point of origin to the point at which the material in the form required for use, is

[1] "f.o.b., free on board: delivered on board and into a carrier without charge [13:525]."

first received for subsequent distribution in the military supply system; (2) the cost of such movement.

Second Destination Transportation: (1) the subsequent movement of property for intradepartment or interdepartment distribution from the point of storage at which originally received from f.o.b. point of origin; (2) the costs of such movement [22:124].

Second Destination Transportation funds support the cost of cargo movements from continental U.S. (CONUS) depots to field activities worldwide, of intertheatre and intratheatre shipments overseas, of Army Post (APO) mail, of some civilians on permanent change of station overseas, and of materials between CONUS installations and major stock points. In addition, SDT covers CONUS port handling charges and overseas port operating costs. Costs involved in special assignment airlift for movement of cargo which requires special consideration due to security, weight, size of cargo, and/or mission requirements are supported by SDT (14:3; 19:pp.10-18 to 10-19).

The Military Services are responsible for the planning, programming, and expending of SDT funds, which comprise a separate line item under Major Force Program (MFP) VII: Central Supply and Maintenance, in the Operations and Maintenance budget of each Service (12; 14:3-4). Within the Air Force, the Air Force Logistics Command (AFLC) is the largest user of SDT funds. Approximately 75 to 80 percent of the total Air Force SDT funding each year is allotted to AFLC, almost 15 percent is allotted to the Directorate of

Administration, Office of the Chief of Staff, and the remainder is provided to the other Air Force Commands (14:32).

The SDT budgeting and funding responsibilities within AFLC are divided into six major categories, or modes of transportation: Military Airlift Command (MAC), Military Sealift Command (MSC), Commercial Air, Commercial Surface, Logistics Airlift (LOGAIR), and Port Handling Operations. Excluding LOGAIR, the Air Force flying hour program by overseas geographic area is the basis for the development of tonnage and budget requirements for the five modes (9:12; 14:34). Each of the five modes support five geographic areas: European, Pacific, Alaskan, Southern, and Northeastern. The areas correspond to the four major Air Force overseas commands, U.S. Air Forces in Europe (USAFE), Pacific Air Forces (PACAF), Alaskan Air Command (AAC), and U.S. Air Forces Southern Command (USAFSO), and to the consolidation of the northern radar sites which comprise the Northeastern area (9; 12).

MAC and MSC are the primary modes which support the movement of general cargo shipments from and between aerial and water ports in the CONUS and the overseas areas (9; 12; 19:p.10-19). The budget required to cover the SDT costs of MAC and MSC is flying hour related and encompasses approximately $150 million, which is 50 percent of all SDT

within MFP VII, and is 70 percent of the total provided to AFLC (11; 12).

## Justification

Since the early 1960s, budget forecasts have been based upon the Air Force flying hour programs by overseas geographic area. The present tonnage estimating method depends on a tonnage transported per flying hour ratio being applied to the flying hour programs of future budget years (12; 14:34). The tonnage, and hence the budget estimates, are projected for five future years to coincide with the Five Year Defense Program (FYDP) (12).

The ton/flying hour ratio, also referred to as the delta factor, and the future budget are recomputed manually for each mode of transportation three times a year for the FYDP, and also each time the flying hour program changes (12). To obtain the final budget estimate for MAC and MSC, a tonnage estimation computation is accomplished for each geographic area based on programmed flying hours within the areas. Tonnage and budget estimates for each geographic area are computed separately for two reasons:

1. The costs of cargo movements differ and are related to:

    a. Flying distance

    b. Tonnage moved

    c. Weather

2. Flying hours are programmed by, and are changed for, major commands.

The task is time-consuming considering other budget computations must be accomplished manually for the other modes of transportation by geographic area, excluding LOGAIR, for the total SDT program within AFLC. When flying hour programs change, or when speculative questions are asked by HQ USAF, short lead times are experienced for recomputations, which only increases the probability of human error in manual estimation of tonnage requirements and in final budget forecast submission (9; 11; 12).

Previous tonnage estimates, as predicted by programmed flying hours, have usually been directly related mathematically, such that an increase in flying hours yielded a positive delta factor and an increase in tonnage estimates. Yet, at times, an inverse relationship occurs which is presumed to have been caused by previous miscalculations (12). These occurrences resulted in the necessity for periodic rejustification of the method to higher echelons to avoid possible reductions in the SDT budget submissions. Therefore, to eliminate the probability of an inverse relationship, deviations from and juggling of the base period[2] for each geographic area within each mode of transportation

[2]"Base period: that period of time for which factors were determined for use in current planning and programming [22:20]."

became necessary each time the budget estimates were computed. For example, the base period for the Pacific area for MAC might be nine months one year and sixteen months the next year; while for the same area for MSC, the base period might be fifteen and twenty-four months. After the manipulation of the historical data, a positive delta factor would be reflected and would provide a direct relationship to the programmed flying hours (12). The additional computations and adjustments contributed to wasted manhours, miscalculations, inconsistencies, and potential future errors (9; 11; 12).

Consequently, although the method is relatively simple, apprehension exists at various Air Force levels as to the method's validity and reliability (9; 11; 12). For FY77, only 95 percent of the programmed flying hours were flown which should have equated to approximately the same percentage of the estimated budget being spent, leaving approximately $7 million in excess. However, only $2.5 million remained. The expenditure of the other $4.5 million, and the movement of subsequent tonnage, cannot be explained utilizing the delta factor technique (12).

All too often, furnishing valid justification to preclude a budget reduction, without an accompanying reduction in flying hours, has been difficult because of previous budget overestimations (1:7; 9; 12). The Office of the Secretary of Defense examiners do not consider the present

method of tonnage estimation as an acceptable and understandable decision-making tool for budget estimations (3:1; 5; 11; 12). Because a validated method is not being utilized, higher echelons hesitate to accept or approve budget submissions without a myriad of justification (9; 11; 12).

## Scope

In limiting the scope of this research, numerous variables and data sources were considered. The final selections were predicated on the availability of sufficient, reliable information for resolution of the problem.

### Variables

The Management Sciences Division, HQ AFLC/XRS, recently conducted a study which was to provide support for the use of flying hours as a predictor of tonnage estimates for MAC and MSC (3:1). Twenty-one variables[3] were identified as being directly or indirectly related to the SDT program for MAC and MSC. The study revealed that both the number of flying hours and the number of manpower authorizations per geographic area had high overall correlation to tonnage estimations, but not in all geographic areas. The flying hour variable was not considered "a totally valid predictor of tonnage requirements. . . . However, it is the most logical factor to use . . . given the data

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[3]A listing of the variables is provided in Appendix A (3:3).

available [3:]." Manpower was not mentioned in the study as being a valid predictor. However, during a personal interview with the study's author, he stated that manpower appeared as good as, if not better than, flying hours as a tonnage predictor (4).

Therefore, based on the XRS study and on an analysis of the identified variables, nineteen of the variables were not considered applicable or feasible for one or more of the following reasons. First, the time constraint imposed during this research effort precluded reconstruction of data bases from data systems which had undergone recent modification, and had thereby altered the data content. Second, many variables did not have a historical data base which would provide sufficient information for analysis of the research problem. Third, none of the nineteen variables had programmed information for future projections, which is considered useful in predicting future tonnage estimates (3:3; 4; 6; 9; 12).

Flying hours and manpower were selected as the independent variables most likely to predict tonnage requirements in this research effort. An *a priori* relationship appears to exist between these variables in that tonnage transported supports the flying hours and manpower in each geographic area (9; 11). "Historical data shows a fairly constant relationship over the years between personnel assigned from year to year, and the material required to

support a man for one year [1:9]." Further, flying hours and manpower data are programmed for future projections and are available from USAF program documents (8; 11; 20; 21). Also, the historical data bases for the variables have not undergone modification in the last few years (8; 12). Thus, although both variables were not considered as valid predictors of tonnage estimates by the XRS study, sufficient justification exists for utilization of these variables (9; 11; 12).

Data Source

In limiting the scope of this study, MAC was chosen as a data source. As was previously stated, MAC and MSC SDT programs are allotted approximately 50 percent of the total MFP VII funds, of which MAC alone utilizes 33 percent of this total funding. The remaining five modes of transportation each account for 18 percent or less (12). Although the other modes are flying hour related, except for LOGAIR, they do not have the well established data system that MAC has (9; 12). MAC is the only data source which has not modified or changed its method for compiling data in the last ten years. Further, with each mode having five geographic areas from which to gather sufficient data, the time constraint imposed a formidable hinderance to efficiently formulate and test a new tonnage estimation model (12). Hence, this study was directed towards determining

if the variables chosen do predict tonnage estimates, and if a model can be developed for MAC's five geographic areas.

## Research Objectives

The objectives for derivation of future SDT tonnage estimates and budget requirements are to:

1. Determine whether flying hours, manpower, or both are significantly reliable predictors of tonnage estimates.

2. Develop a computerized model for computation of SDT tonnage and budget estimates, if the variable(s) chosen are significantly reliable predictors.

## Research Hypothesis

A computerized model can be developed to forecast tonnage and budget estimates, utilizing flying hours and/or manpower as predictors.

# CHAPTER II

# METHODOLOGY

The problem, as previously stated, is that a validated method does not exist for computation of tonnage estimates to derive future SDT budget requirements. The prime objective of this research was to determine whether flying hours, manpower, or both are significantly reliable predictors of tonnage estimates. If one or both of the variables were a reliable predictor, the second objective would be achieved through computerization of the optimal regression model chosen.

## Data Acquisition

### Variables Defined

Flying Hours: The independent variable, flying hours, is the total number of hours flown by the various Air Force aircraft which are (1) assigned to each overseas geographic area, or (2) transient in each overseas geographic area in excess of thirty days. The flying hours are not the hours flown by MAC cargo aircraft.

Manpower: The independent variable, manpower, is the total number of Air Force military personnel in each overseas geographic area.

**Short Tons**: The dependent variable, short tons, is the total number of tons of general military cargo transported by MAC to each overseas geographic area for support of Air Force programs and personnel. A short ton is measured as 2000 pounds. The terms tonnage and short tons are used interchangeably throughout this thesis.

## Sample Plan

For the purpose of this research, the population is defined as all tonnage that has been and would be moved by MAC for all five overseas geographic areas. The sample consists of all tonnage transported by MAC during the time period 1 October 1973 to 31 March 1978, by quarter. Both actual and programmed data for this period were utilized. The decision was made to limit the sample in this manner because the influences of the Vietnam War were not considered representative of peacetime tonnage movements and because the data for the selected period were readily available.

## Data Sources, Description and Validity

The actual and programmed data used to describe the variables were obtained from HQ AFLC/LORET. The data were accumulated from various sources within the Air Force[4] and were assumed to be valid as documented in accordance

[4]See Appendix B for a list of data sources for the variables (12; 20; 21).

with Air Force directives (8; 12). It was further assumed that errors, if any, in data documentation at the working level and in the transmission to the computer systems were random in nature and did not affect the overall validity of the data.

Data Modification

The data received were for the period 1 October 1973 to 31 March 1978, by quarter, except for actual manpower data. Actual manpower data could only be obtained for the period 1 October 1974 to 30 September 1977, for all five geographic areas. Further, these data were *year-end* figures, that is, the end of the fourth quarter for fiscal year (FY) 1975, 1976, and 1977. Therefore, modification of the actual manpower data was necessary to:

1. Homologize this data with all other data for ease of manipulation and computation.

2. Provide a sufficient quantity of data points from which to mathematically develop tests and a model.

3. Avoid the loss of any explanatory power in development of a model if the data were not utilized.

To modify the data such that quarterly rather than year-end data were available, programmed manpower data were utilized to estimate quarterly actual manpower. First, programmed manpower data for fourth quarter FY73 (April-June 1973) was assumed to be a sufficient estimate of actual

manpower for the same period. Second, a linear relationship was assumed to exist between the fourth quarter of FY73 and the fourth quarter of FY75. Hence, quarterly estimates of actual manpower were obtained for FY74 and FY75. To obtain actual quarterly manpower data for FY76 and FY77, including fiscal quarter 7T, a linear relationship was assumed to exist from fourth quarter FY75 to fourth quarter FY76, and from fourth quarter FY76 to fourth quarter FY77.

Apprehension regarding the effects of the data modification is expected. However, to fully utilize available data, the procedure was the most logical. Since the actual manpower variable does not appear in the final model, the validity of the model has not been diminished.

## Model Development

The differences between this research effort and the XRS study were twofold. First, XRS used a mixture of both actual and programmed data within one model in an attempt to provide support for flying hours as a predictor of tonnage estimates (4; 9). This research effort considered both actual and programmed data as separate entities to determine whether flying hours, manpower, or both were reliable predictors of tonnage estimates. Second, the previous study used sample data from the period FY73 to FY76 without consideration of the events associated with the Vietnam War (3:3; 4; 6). The current effort utilized data from the

period 1 October 1974 to 31 March 1978, thereby eliminating the effects of the Vietnam War.

The first step in any model development is to plot the data to determine what type of relationship exists, whether linear or curvilinear (10). As illustrated in Figures 1 and 2,[5] a linear relationship appears to exist between flying hours and tonnage, and manpower and tonnage. However, a gap, or discontinuity, between data points of the apparently linear relationship is evident in both figures. Whenever a linear regression function changes slope, and also jumps, the technique utilized to deal with the function is called discontinuous linear regression (10; 15:316). Linear regression analysis is a technique whereby one or more quantitative variables are used to predict the value of another quantitative variable (7:9; 10; 18:391).

## Discontinuous Linear Regression

On occasion, a regression of "Z" on "X" and/or "Y" may not follow a uniform linear relation. The regression function may change slope at some point and/or may shift some constant value up or down with regards to the Z-axis. To account for the occurrences, discontinuous linear regression (DLR) must be used (15:313-316).

Upon examination of the scattergrams of the data, DLR seemed appropriate for discontinuities appeared to

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[5]See Appendix C for a listing of data utilized for the figures.

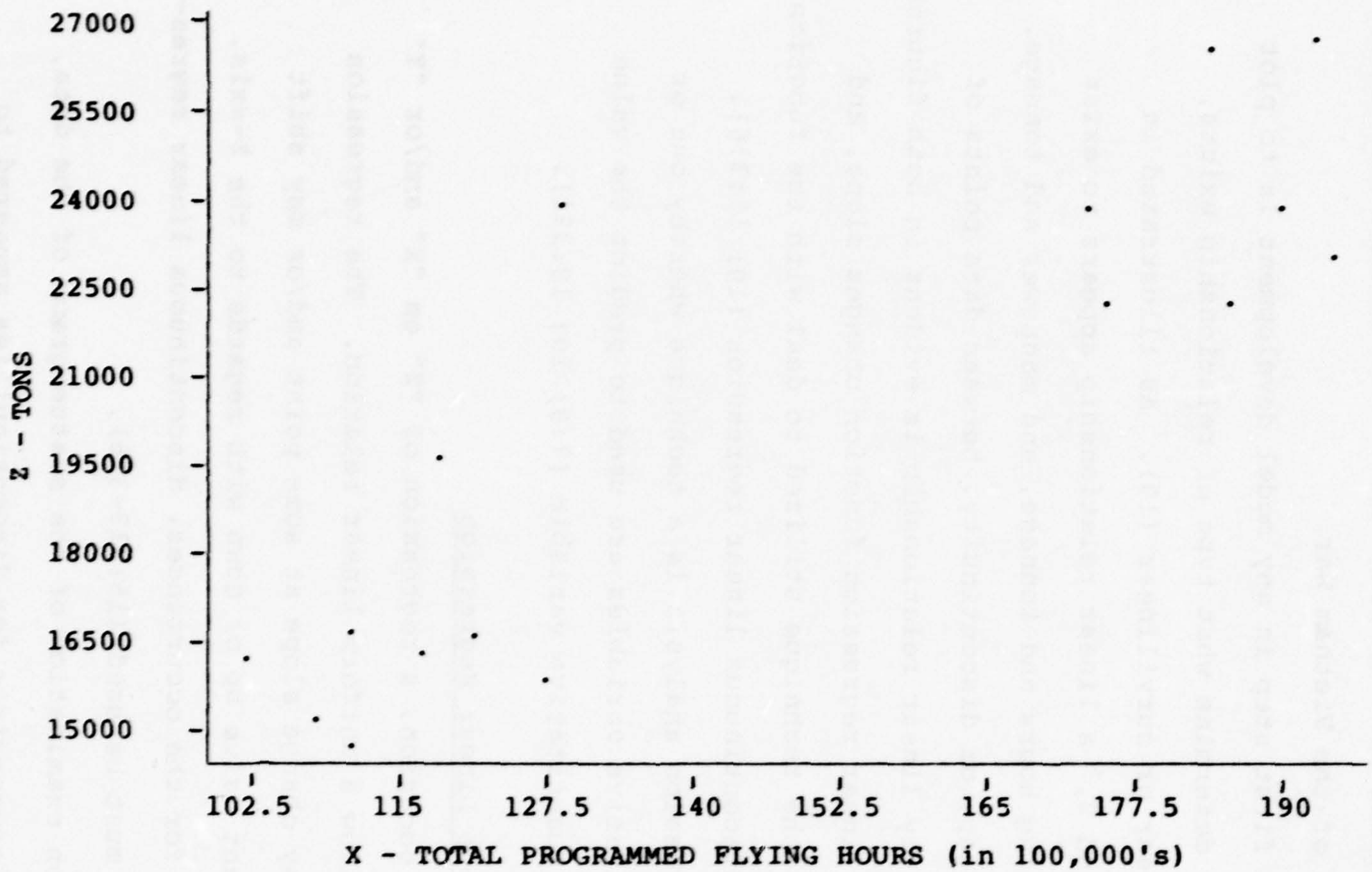


Fig. 1. Actual Tonnage Versus Total Programmed Flying Hours

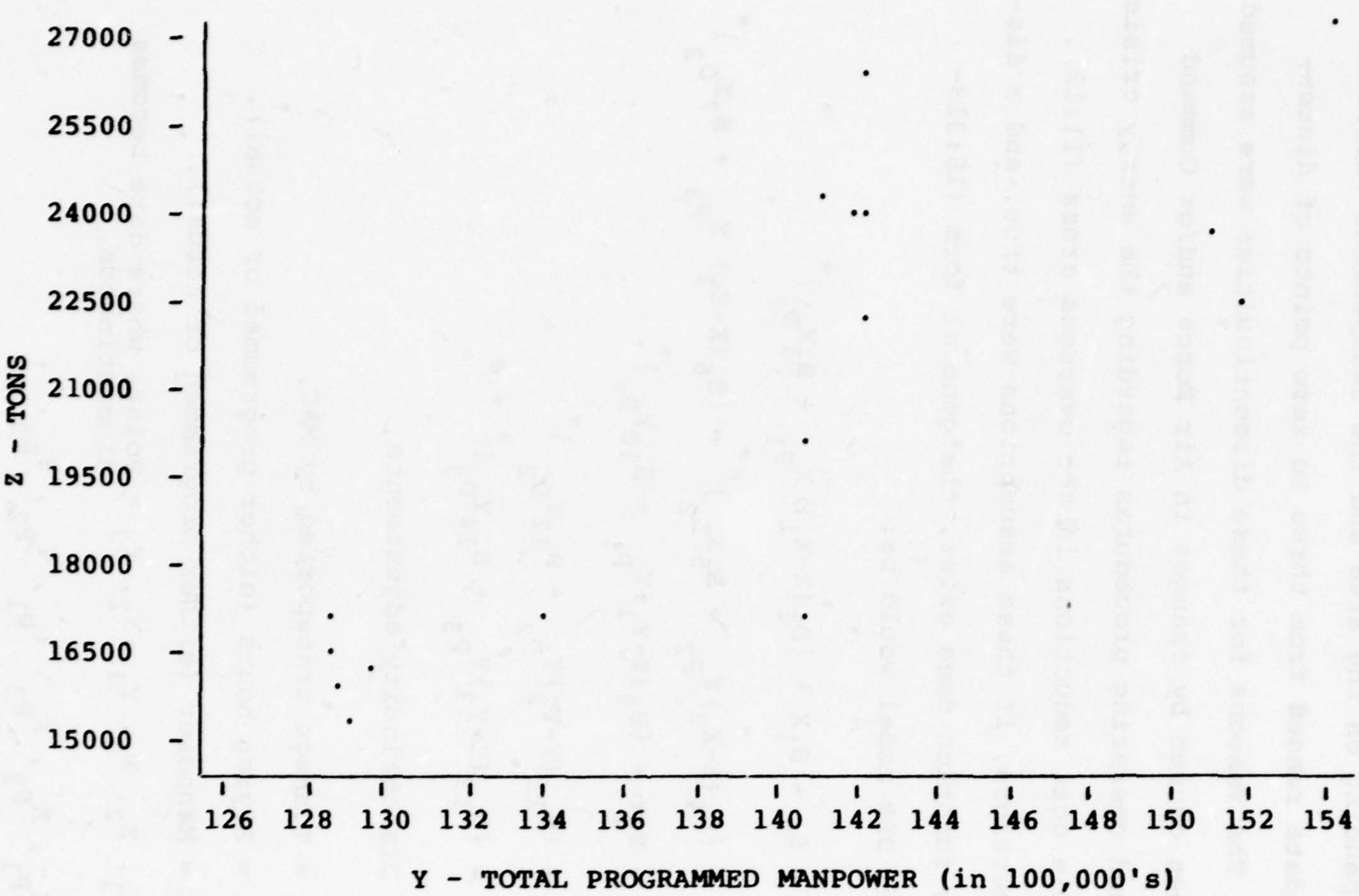


Fig. 2. Actual Tonnage Versus Total Programmed Manpower Authorizations

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exist. Depending on the area and the independent variables used, the data ranged from three to zero points of discontinuity. The reasons for these discontinuities were assumed to have been caused by changes in Air Force and/or Command policies and operating procedures regarding the energy crisis, and possible cost reductions in the overseas areas (11:12).

Therefore, if these assumptions were true, and a discontinuous function does exist, the general form (15:313-316) of the DLR model would be:

$$
\begin{aligned}
Z = {} & B_0 + B_1X + \{B_2(X-X_1)\, X_{P_1} + B_3X_{D_1}\}^* \\
& + \{B_4(X-X_2)X_{P_2} + B_5X_{D_2}\}^* + \{B_6(X-X_3)\, X_{P_3} + B_7X_{D_3}\}^* \\
& + B_8Y + \{B_9(Y-Y_1)Y_{P_1} + B_{10}Y_{D_1}\}^* \\
& + \{B_{11}(Y-Y_2)Y_{P_2} + B_{12}Y_{D_2}\}^* \\
& + \{B_{13}(Y-Y_3)Y_{P_3} + B_{14}Y_{D_3}\}^* + e
\end{aligned}
$$

* Discontinuity adjustments

where: $Z$ = Tonnage transported by MAC,

$X$ = Flying hours (either programmed or actual),

$Y$ = Manpower (either programmed or actual),

$X_1$, $X_2$, $X_3$, $Y_1$, $Y_2$, $Y_3$ = Points where data becomes discontinuous,

$X_{P_1}$, $X_{P_2}$, $X_{P_3}$, $Y_{P_1}$, $Y_{P_2}$, $Y_{P_3}$,

$X_{D_1}$, $X_{D_2}$, $X_{D_3}$, $Y_{D_1}$, $Y_{D_2}$, $Y_{D_3}$ = Indicator (dummy variables) defined as:

$$X_{P_1} = X_{D_1} = \begin{cases} 1, & \text{if } X > X_1 \\ 0, & \text{otherwise} \end{cases}$$

$$X_{P_2} = X_{D_2} = \begin{cases} 1, & \text{if } X > X_2 \\ 0, & \text{otherwise} \end{cases}$$

$$X_{P_3} = X_{D_3} = \begin{cases} 1, & \text{if } X > X_3 \\ 0, & \text{otherwise} \end{cases}$$

$$Y_{P_1} = Y_{D_1} = \begin{cases} 1, & \text{if } Y > Y_1 \\ 0, & \text{otherwise} \end{cases}$$

$$Y_{P_2} = Y_{D_2} = \begin{cases} 1, & \text{if } Y > Y_2 \\ 0, & \text{otherwise} \end{cases}$$

$$Y_{P_3} = Y_{D_3} = \begin{cases} 1, & \text{if } Y > Y_3 \\ 0, & \text{otherwise} \end{cases}$$

$B_0, \ldots, B_{14}$ = Coefficients of regression, and

e = The explained component in each value that is not explained by the independent variables.

To illustrate how an equation was formulated, the following example is provided. In examining the scattergrams in Figures 1 and 2, discontinuities not only appeared to exist at 130,000 and 140,000 flying hours, but also at 130,000, 140,000 and 150,000 manpower authorizations. The general form of this example DLR equation now becomes:

$$Z = B_0 + B_1X + \{B_2(X-130000)X_{P_1} + B_3X_{D_1}\}$$
$$+ \{B_4(X-140000)X_{P_2} + B_5X_{D_2}\} + B_8Y$$
$$+ \{B_9(Y-130000)Y_{P_1} + B_{10}Y_{D_1}\}$$

$$\{B_{11}(Y-140000)Y_{P_2} + B_{12}Y_{D_2}\}$$

$$+ \{B_{13}(Y-150000)Y_{P_3} + B_{14}Y_{D_3}\} + e$$

where: $X_1 = 130{,}000$,

$X_2 = 140{,}000$,

$Y_1 = 130{,}000$,

$Y_2 = 140{,}000$,

$Y_3 = 150{,}000$, and

$X_3 = X_{P_3} = X_{D_3} = B_6 = B_7 = 0.$

Basic Assumptions

The following assumptions were required to justify use of DLR and to fit the curve (regression line) to the independent data points.

1. The expected value, or mean, of each error component, e, was zero as measured with respect to the regression line.

2. The variance of the eror components was constant.

3. The error components were uncorrelated, or statistically independent.

4. The error components were normally distributed about the regression line.

5. The number of sample observations was greater than the number of estimated population parameters.

6. Sample observations were linearly independent.

7. Measurement errors were associated with the dependent variable, not with the independent variables (10; 15:316; 18:545; 23:265).

Since multiple observations were not available for each data point, the assumptions could not be tested to verify justification. However, they were assumed to hold for the data being utilized.

Model Manipulation

A computer program, the Statistical Package for the Social Sciences (SPSS), was utilized for construction of the models through linear regression analysis. The Regression Subprogram was used to derive the DLR equations necessary for determination of the optimal regression model (16: 320-367).

First, a set of twelve equations was obtained utilizing SPSS: six equations utilizing programmed data and six equations utilizing actual data. Consider first the six equations obtained from the programmed data. The programmed data for each geographic area was used to derive an equation which could be used to predict the tonnage moved to that area. Thus, five equations were derived, one for each area. The last of the six equations was derived utilizing the total of all programmed data for all areas to predict total tonnage moved. The six equations utilizing actual data were similarly developed.

Second, from these twelve equations, four models were developed. Consider first the programmed data equations. The five area equations were summed, without loss of integrity to the individual equations, to form one model. In other words, each equation represented the tonnage moved to that area, and the total sum of these five areas was the total summed tonnage shipped. The last equation formed another model. The six equations utilizing actual data were similarly used to form two additional models.

Before comparing the models, an explanation of the equations' value inputs to be used is necessary. In using these models as predictive tools, actual value inputs could not be utilized because they would not exist. For example, in forecasting for FY82 in FY78, actual value inputs would not be available for that future period. Therefore, programmed value inputs would have to be used.

Finally, in determining which model was optimal, the mean average deviation (MAD) per quarter was used. Programmed data available for the period 1 October 1974 to 31 March 1978 was utilized to determine whether the tonnage estimated by each model was the same as the actual tonnage transported during the same period. The model which yielded the lowest MAD was considered the optimal model. The formula (17:663) used was:

$$MAD = \frac{\sum_{t=1}^{n} Z-\hat{Z}}{n}, \quad n=1,\ldots,14$$

The optimal model was subjected to statistical and criteria tests to determine its validity, as specified in the next section. If the model failed to be valid, the second best model was to be tested, and so on until all models were exhausted. If any one of the models was statistically validated, external tests were applied to determine whether the ultimate model or the present delta factor method was most accurate.

Once the most accurate method was determined, a FORTRAN program was developed for computations of the tonnage and budget estimates (17:1-293).

## Model Validation

### Statistical Tests

The classical, or sampling-theory, hypothesis test was conducted to determine if a relationship existed between the dependent and independent variables (2:372). For the final DLR model:

$$H_0: \; B_i = B_{i+1} = \ldots = 0, \; i=1,\ldots, p-1$$

$$H_1: \; \text{At least one } B \neq 0$$

where: p = The degrees of freedom lost due to $b_0$, $b_1, \ldots,$ $b_{p-1}$ estimated simultaneously (10).

The F test, which was used in the DLR model, compared the $F_0$ value, which was found using:

$$F_0 = \frac{\text{variation explained by regression}}{\text{unexplained variation}}$$

with the F critical, $F_c$, found in any statistics textbook. The $F_0$ value must be greater than $F_c$ to reject the null hypothesis, $H_0$, and to conclude a statistically significant relationship existed between the dependent and independent variables (2:395-397; 10; 18:549-550; 23:340).

An F test was also used to test for the problem of multicollinearity[6] in the DLR model (10). The test hypothesis (10) for the model was:

$H_0$: $B_i=0$, for each i; where i=1,..., p-1

$H_1$: $B_i \neq 0$

The test statistic was:

$$F_0 = \frac{(\Delta EV) \text{ due to } X_i}{UV/n-p}$$

where: $(\Delta EV)$ due to $X_i$ = The change in explained variation attributable to the presence of a particular independent variable, $X_i$. Also referred to as the net or marginal contribution to EV,

$X_i$ = Independent variable, flying hours or manpower, where i-1,...,p-1,

UV = Unexplained variation, and

n = The number of sample observations.

---

[6]Multicollinearity is the effect and existence of an inter-correlation between independent variables which reduces the ability to explicate the explanatory power as owing to the presence of a particular independent variable (10; 23: 292-295).

If the $F_0$ value was greater than the $F_c$ value, the null hypothesis, $H_0$, was rejected, thereby concluding that there was statistical significance to the regression of $X_i$ at the designed equivalent-α level of significance, which was:

$$\text{equivalent-}\alpha = \frac{\alpha}{p-1}$$

All independent variables were tested simultaneously. Although multicollinearity may cause statistical significance tests to fail, the predictive ability of the final model would not be necessarily impaired (10).

## Criteria Tests

A subjectively chosen level of confidence of 90 percent was used to determine the statistical significance of the results of the DLR model. This confidence level was chosen because it is a generally accepted criteria test for new research (10).

A criterion used to evaluate the predictive power of the model was a subjective test on the coefficient of determination ($R^2$). This coefficient, referred to as the measure of efficiency of the regression line, was computed as part of the SPSS output, but could be found (18:412) using:

$$R^2 = \frac{\text{variation explained by regression}}{\text{total variation}}$$

An $R^2$ approximately equal to 0.80 is normally considered sufficient to conclude that a model is effective in predicting the dependent variable (10; 18:408-413,548; 23:341-342). The model with the highest predictive power was preferred.

## External Test

To test the final model in real world terms, programmed data available for the period 1 October 1974 to 31 March 1978, was utilized to determine whether the tonnage estimated by the model was the same as the actual tonnage transported during the same period. The model's predictions were compared with the predictions obtained from the present delta method, utilizing the mean average deviation (MAD) per quarter. The following formula (18:663) was used:

$$MAD = \frac{\sum_{t=1}^{n} Z-\hat{Z}}{n}, \quad n=1,\ldots,14$$

An improvement in overall estimation was expected from the final research model. However, if the model was not more accurate, the second objective could not be met.

## Limitations

The model developed from this research will be valid only for predicting estimates of tonnage programmed to be transported by MAC for the total of the overseas areas.

Any inferences to other modes of transportation must be based on a subjective evaluation of the respective situation.

# CHAPTER III

# MODEL DETERMINATION

This chapter includes a summary of results from the SPSS Regression Subprogram. The data utilized to compute the twelve equations are listed in Appendix D. The DLR equations and the residuals by area by quarter, are listed in Appendices E and F, respectively. Interpretation of the results provides the reasons for selection of the final model, which was considered most applicable in determining tonnage estimates.

## Presentation of Results

Tables 1 and 2 illustrate the results of the statistical tests for each of the twelve equations. The mean average deviation (MAD) for each equation was computed utilizing the residuals listed in Appendix F.

## Interpretation of Results

Before discussing the four models which were developed, an explanation of why the Southern area showed such a low $R^2$ and why the data was not statistically significant seems appropriate. A review of the data revealed that only 322 short tons per quarter on the average were shipped to that area. Deviations in tonnage from the

TABLE 1

OUTPUT WITH PROGRAMMED DATA

| Area \ Statistics | $R^2$ | $F_o$* | $F_c$ | df** | MAD*** |
|---|---|---|---|---|---|
| European | 0.595 | 5.881 | 2.61 | 3, 12 | 49 |
| Pacific | 0.949 | 27.935 | 2.55 | 6, 9 | -315 |
| Alaskan | 0.467 | 5.699 | 2.76 | 2, 13 | - 36 |
| Southern | 0.088 | 0.625 | 2.76 | 2, 13 | - 3 |
| Northeastern | 0.902 | 36.637 | 2.61 | 3, 12 | - 27 |
| Total Data | 0.886 | 31.212 | 2.61 | 3, 12 | - 8 |

*If $F_o > F_c$, the results are statistically significant.

**With an $\alpha$ level of 0.10, the df (degrees of freedom) are indicated with the upper and lower values.

***MAD is the mean average deviation from actual tonnage per quarter of the equation's forecast.

TABLE 2

OUTPUT WITH ACTUAL DATA

| Area \ Statistics | $R^2$ | $F_o$* | $F_c$ | df** | MAD*** |
|---|---|---|---|---|---|
| European | 0.577 | 5.445 | 2.61 | 3, 12 | -2358 |
| Pacific | 0.991 | 164.170 | 2.55 | 6, 9 | 292 |
| Alaskan | 0.671 | 8.161 | 2.61 | 3, 12 | - 215 |
| Southern | 0.059 | 0.407 | 2.76 | 2, 13 | - 37 |
| Northeastern | 0.921 | 31.914 | 2.54 | 4, 11 | - 214 |
| Total Data | 0.902 | 36.705 | 2.61 | 3, 12 | 1120 |

*If $F_o > F_c$, the results are statistically significant.

**With an $\alpha$ level of 0.10, the df (degrees of freedom) are indicated with the upper and lower values.

***MAD is the mean average deviation from actual tonnage per quarter of the equation's forecast.

average without proportional-like deviations in flying hours and manpower drastically reduced the predictive power of the equation. As shown in Appendix F, the actual tonnage moved fluctuated without corresponding changes in flying hours and manpower. Thus, the results showed a low correlation and an equation which was not statistically significant. However, because less than 2 percent of the total tonnage moved was shipped to the Southern area, the absence of a high correlation would not have a significant impact on the overall model.

The four models were developed from the twelve equations as previously stated. The models, two utilizing programmed data and two utilizing actual data, were compared to determine which was the most optimal as indicated by the lowest MAD value.

The first model, developed from the five area equations summed using programmed data, had a MAD of -332 short tons per quarter. The second model, which was the total of all programmed data, had a MAD of -8 short tons per quarter. The third model, developed from the five area equations summed using actual data had a MAD of -2531 short tons per quarter. The fourth model, which was the total of all actual data, had a MAD of 1120 short tons per quarter. The negative short tons indicated that the model overestimated tonnage requirements for the period 1 October 1974 to 31 March 1978.

Clearly, the second model yielded the most optimal result. This model was tested to determine its validity. If the model failed to be valid, the first model would be tested, as indicated in Chapter II.

## Final Model Validation

Based on the results of the analysis in Table 1 and the tests established in Chapter II, the Total Data equation was statistically significant. In other words, a significant relationship existed between the independent variables and the dependent variable (2:395-397; 10; 18:549-550; 23:340). Also, the $R^2$ of 0.886 was greater than the previously established criterion of 0.80. This indicated that the model was effective in predicting the dependent variable (10; 18:408-413,458; 23:341-342). Therefore, the model was considered to be statistically valid.

The final model was practical because of its pervasiveness. Fluctuations in the individual areas were counteracted by each other, thereby balancing the overall effects of the separate areas. In addition, the final model, which utilized programmed data, produced more accurate results, according to the MADs, than did the two models using actual data. This was because the latter two models yielded results which were predicated on programmed inputs into equations derived from actual data. Logically, the

final model was the most valid because programmed inputs were used to forecast programmed tonnage.

## CHAPTER IV

## MODEL VALIDATION

The data for the estimates computed from the present Delta (Δ) Method used by AFLC/LORET and for the actual tonnage shipped overseas were obtained from LORET (12) (see Table 3). The estimates for the final model were part of the SPSS output.

### Presentation and Interpretation of Results

Ordinarily, an overestimation of tonnage is better than an underestimation for various reasons (12). First, an overestimation of tonnage would provide a sufficient budget to meet unforeseen surges in tonnage requirements. Second, with a reasonable excess of funds, the increased costs of inflation could be met. Finally, an overestimation would preclude the necessity to request and await additional funds to move needed tonnage overseas.

However, continuous overestimation can cause problems. One is that the creditability of office submitting the budget may be questioned. Another problem is that substantial justification may become necessary to obtain funds. Finally, funds that may be needed elsewhere are not being utilized to the full extent possible.

TABLE 3

COMPARISON OF METHODS

| FY QTR | Actual Tonnage (Z) | Δ Method | | Final Model | |
|---|---|---|---|---|---|
| | | $\hat{Z}$ | $Z-\hat{Z}$ | $\hat{Z}$ | $Z-\hat{Z}$ |
| 75-2 | 23895 | 25898 | -2003 | 23762 | 133 |
| -3 | 22233 | 26083 | -3850 | 23774 | -1541 |
| -4 | 23905 | 27286 | -3381 | 23813 | 92 |
| 76-1 | 24102 | 21984 | 2118 | 23512 | 590 |
| -2 | 19748 | 20224 | - 476 | 17703 | 2045 |
| -3 | 16778 | 19224 | -2446 | 17683 | - 905 |
| -4 | 17123 | 20180 | -3057 | 17004 | 119 |
| 77-T | 16315 | 20228 | -3913 | 16642 | - 327 |
| -1 | 16569 | 18008 | -1449 | 16473 | 96 |
| -2 | 15899 | 18913 | -3024 | 16491 | - 592 |
| -3 | 17109 | 19046 | -1937 | 16478 | 631 |
| -4 | 15452 | 19212 | -3760 | 16519 | -1067 |
| 78-1 | 16904 | 18786 | -1882 | 15955 | 949 |
| -2 | 15634 | 19662 | -4028 | 15970 | - 336 |

The Delta Method has caused such problems for AFLC/LORET. As shown in Table 3, the method excessively overestimated tonnage to be moved for thirteen of the fourteen quarters. The MAD value was -2363 short tons per quarter. Since tonnage for each area was computed separately, the summed total did not consider fluctuations. The average overestimation of tonnage to be moved per quarter was 12.64 percent of what was actually moved.

The final model overestimated tonnage in six of the fourteen quarters, producing a MAD value of -8 short tons per quarter. The tonnage overestimation was 0.04 percent per quarter. The model provided a closer estimate of tonnage moved in every quarter except for FY76-2. This exception resulted from the fact that more tonnage was shipped than was expected although actual flying hours and manpower decreased significantly (see Appendix D, Total Data). Yet overall, the model developed provided a more accurate estimation of tonnage to be moved.

## Computerization of the Final Model

The SPSS program required to derive the variables and their coefficients used in the final model is listed in Appendix G. The FORTRAN program necessary to compute the budget estimate per area per quarter is listed in Appendix H. The cost per ton per area is an input to the FORTRAN program and is not a concern in this research effort.

# CHAPTER V

## CONCLUSIONS AND RECOMMENDATIONS

### Conclusions

The purpose of this research was to develop a better method for computing tonnage estimates which are used to derive future budget requirements. Discontinuous Linear Regression provided a more accurate estimation of tonnage to be moved than did the current Delta Method.

In development of the final model, several areas required consideration. First, of the many independent variables affecting tonnage, only two, flying hours and manpower, were known to be predictive in nature and programmed for future years. Second, although the SDT is divided into six major categories, only one, MAC, has an information system capable of providing necessary data of tonnage actually moved. Finally, the data sample had to be representative of the current situation so as to provide a more realistic comparison.

Once these judgements were made, the determination of the final model depended on the reliability and validity of the variables and data, and whether actual or programmed data would provide the optimal solution. As was shown, the final model was developed utilizing both programmed

flying hours and manpower. The comparison between the Delta Method and the final model illustrated that the latter provided a more accurate estimate of tonnage to be moved.

With the development of the computer programs, several advantages of the final model over the Delta Method are evident. First, the base period need not be arbitrarily chosen for each area since the final estimates will directly relate to changes in the independent variables. Next, manual computations will not be necessary, and results can be obtained faster. Third, the model has been shown to be a valid technique which provides a closer, quarterly estimation of tonnage. Finally, and probably the most important, justification for over or underestimations can be understandably and clearly explained to higher echelons. A more accurate picture of tonnage to be moved and of the funds necessary to support these shipments should insure future budget allocations are not in excess of those required.

Finally, the model and the programs developed in this research effort are adaptive. Their value will increase as more data are accumulated. The discontinuity should be absent within two years, providing the present circumstances are not drastically altered as was the case in 1973 and 1975. With the elimination of any discontinuity through substitution of FY78 and FY79 data for FY74 and FY75 data, a simpler multiple linear regression can be used

to compute tonnage estimates. The use of hand calculators should suffice, and would be as fast as the larger computers.

## Recommendations

Regarding future research in the area of SDT tonnage and/or budget estimates, consideration should be given to these additional subjects:

1. The use of MAC as a data source should be expanded to include the other SDT categories, when and if adequate information systems are developed.

2. Determine which variables affect the short tons moved by LOGAIR and how tonnage estimates can be developed.

3. The inclusion of other independent variables should be considered, if they can be programmed for future years.

4. A better method for determination of the cost per ton per geographic area per mode is one subject which should provide a more accurate estimate of budget requirements.

## Summary

The two objectives of this research effort were accomplished. First, the final model revealed that both programmed flying hours and manpower were reliable predictors of tonnage estimates. Second, a computerized model was

developed for determination of tonnage and budget estimates with programmed flying hours, manpower, and cost per ton as inputs.

APPENDICES

# APPENDIX A

# LIST OF XRS VARIABLES

| Variable | Data Source |
|---|---|
| Requisitions Filled | AFLC/ACM |
| Requisitions | AFLC/ACM |
| Aircraft | AFLC/ACM |
| Engines | AFLC/ACM |
| Receipts GSD* | AFLC/LORF |
| Gross Sales GSD | AFLC/LORF |
| Gross Sales SSD** | AFLC/LORF |
| DPEM*** - Aircraft | AFLC/LORER |
| DPEM - Missiles | AFLC/LORER |
| DPEM - Engines | AFLC/LORER |
| DPEM - Other Major End Items | AFLC/LORER |
| DPEM - Exchangeables | AFLC/LORER |
| DPEM - Area Base Maintenance | AFLC/LORER |
| DPEM - Total | AFLC/LORER |
| Overseas Flying Hours | G022B System |
| Worldwide Flying Hours | G033B System |
| Receipts Off Base - Line Items | LOG-XR(Q) 7507 |
| Receipts Off Base - Tons | LOG-XR(Q) 7507 |
| Issues Off Base - Line Items | LOG-XR(Q) 7507 |
| Issues Off Base - Tons | LOG-XR(Q) 7507 |
| Manpower | USAF/PMR |

*GSD: General Support Division
**SSD: System Support Division
***DPEM: Depot Purchased Equipment Maintenance

APPENDIX B

DATA SOURCES FOR RESEARCH VARIABLES

| Variables | Data Sources |
|---|---|
| I. Actual | |
| 1. Flying Hours, Overseas | G033B System |
| 2. Manpower, Overseas | HQ USAF/PRMP |
| 3. Short Tons | 0027A MAC TONS/ COST SYSTEM |
| II. Programmed | |
| 1. Flying Hours, Overseas | PA 75-2 to PA 79-2 |
| 2. Manpower, Overseas | PM 75-2 to PM 79-2 |

# APPENDIX C

## DATA FOR FIGURES 1 AND 2

| Fiscal Year | Quarter | Programmed Flying Hours | Programmed Manpower | Actual Tonnage |
|---|---|---|---|---|
| 1974 | 2 | 190709 | 154200 | 26843 |
| | 3 | 183069 | 152050 | 22239 |
| | 4 | 188616 | 151310 | 23512 |
| 1975 | 1 | 184068 | 142431 | 26399 |
| | 2 | 174914 | 142250 | 23895 |
| | 3 | 176267 | 142319 | 22233 |
| | 4 | 185665 | 142369 | 23905 |
| 1976 | 1 | 130414 | 141358 | 24102 |
| | 2 | 119099 | 140879 | 19748 |
| | 3 | 114029 | 140873 | 16778 |
| | 4 | 121080 | 133697 | 17123 |
| 1977 | T | 124631 | 129889 | 16315 |
| 1977 | 1 | 103265 | 128958 | 16569 |
| | 2 | 108466 | 128949 | 15899 |
| | 3 | 109735 | 128765 | 17109 |
| | 4 | 110248 | 129169 | 15452 |

APPENDIX D

DATA FOR SPSS COMPUTATION BY AREA

## EUROPEAN AREA

| FY-QTR | Z | X1 | Y1 | X2 | Y2 |
|---|---|---|---|---|---|
| 74-2 | 9847 | 65165 | 71519 | 44928 | 68444 |
| -3 | 7499 | 66872 | 71518 | 48297 | 68460 |
| -4 | 8434 | 72811 | 71581 | 57189 | 68475 |
| 75-1 | 9868 | 66167 | 69226 | 56187 | 68491 |
| -2 | 8877 | 63382 | 69323 | 53200 | 68506 |
| -3 | 7701 | 64172 | 69364 | 50402 | 68522 |
| -4 | 7479 | 72830 | 69368 | 59430 | 68537* |
| 76-1 | 7876 | 67113 | 67713 | 64171 | 68934 |
| -2 | 7522 | 58950 | 67[illegible]88 | 51821 | 69331 |
| -3 | 6576 | 59072 | 67790 | 51897 | 69728 |
| -4 | 5650 | 67007 | 67761 | 42781 | 70125* |
| 77-T | 6469 | 70991 | 67009 | 49861 | 70345 |
| -1 | 8003 | 55223 | 67038 | 50499 | 70565 |
| -2 | 7652 | 56272 | 67029 | 53576 | 70784 |
| -3 | 8122 | 60384 | 66922 | 61441 | 71004 |
| -4 | 7940 | 59550 | 66913 | 64078 | 71224* |
| 78-1 | 8680 | 65292 | 66455 | | |
| -2 | 7563 | 66519 | 66455 | | |

Where: Z = Actual Short Tons Moved
X1 = Programmed Flying Hours
Y1 = Programmed Manpower
X2 = Actual Flying Hours
Y2 = Actual Manpower

Suspected Points of Discontinuity:
X1 = 66500
Y1 = 67600, 69000, 70500
X2 = 46000, 58000
Y2 = 68800, 7000

*Actual year-end data which was used to determine remaining data. See Chapter II, Data Modification.

## PACIFIC AREA

| FY-QTR | Z | X1 | Y1 | X2 | Y2 |
|---|---|---|---|---|---|
| 74-2 | 12712 | 107324 | 63011 | 74282 | 74634 |
| -3 | 11122 | 97578 | 60865 | 80409 | 72406 |
| -4 | 11471 | 96453 | 60124 | 81864 | 70178 |
| 75-1 | 12362 | 99594 | 56229 | 73204 | 67949 |
| -2 | 10872 | 93874 | 55959 | 68050 | 65721 |
| -3 | 10529 | 94123 | 55958 | 67530 | 63493 |
| -4 | 12250 | 94136 | 55982 | 58156 | 61265* |
| 76-1 | 12437 | 48156 | 57284 | 51712 | 57093 |
| -2 | 9185 | 45757 | 56734 | 36387 | 52921 |
| -3 | 7114 | 40378 | 56702 | 31821 | 48750 |
| -4 | 8007 | 38808 | 49692 | 27445 | 44578* |
| 77-T | 6593 | 41044 | 47118 | 30691 | 43679 |
| -1 | 5670 | 37037 | 46168 | 33625 | 42780 |
| -2 | 5629 | 39359 | 46168 | 34231 | 41880 |
| -3 | 5977 | 37492 | 46095 | 34327 | 40981 |
| -4 | 4829 | 38647 | 46508 | 34405 | 40082* |
| 78-1 | 5350 | 38970 | 41530 | | |
| -2 | 5632 | 41150 | 41530 | | |

Where: Z = Actual Short Tons Moved
X1 = Programmed Flying Hours
Y1 = Programmed Manpower
X2 = Actual Flying Hours
Y2 = Actual Manpower

Suspected Points of Discontinuity:
X1 = 70000
Y1 = 49000, 53000, 60000
X2 = 36000, 51000, 70000
Y2 = 48000, 62000

---

*Actual year-end data which was used to determine remaining data. See Chapter II, Data Modification.

## ALASKAN AREA

| FY-QTR | Z | X1 | Y1 | X2 | Y2 |
|---|---|---|---|---|---|
| 74-2 | 2016 | 10684 | 13237 | 9430 | 12553 |
| -3 | 1716 | 10963 | 13234 | 10412 | 12411 |
| -4 | 1877 | 11696 | 13235 | 11507 | 12269 |
| 75-1 | 2276 | 13319 | 12760 | 11652 | 12127 |
| -2 | 2155 | 12155 | 12752 | 7401 | 11985 |
| -3 | 2131 | 12469 | 12781 | 8081 | 11843 |
| -4 | 2160 | 13176 | 12803 | 9085 | 11701* |
| 76-1 | 2310 | 10128 | 12095 | 8124 | 11603 |
| -2 | 1973 | 9485 | 12139 | 7825 | 11506 |
| -3 | 1716 | 9697 | 12138 | 8022 | 11408 |
| -4 | 1794 | 10128 | 12056 | 7550 | 11310* |
| 77-T | 2023 | 9718 | 11622 | 8973 | 11109 |
| -1 | 1792 | 8217 | 11616 | 7707 | 10907 |
| -2 | 1652 | 9514 | 11616 | 9954 | 10706 |
| -3 | 1676 | 8981 | 11612 | 8722 | 10504 |
| -4 | 1713 | 9155 | 11612 | 8629 | 10303* |
| 78-1 | 1972 | 8477 | 11211 | | |
| -2 | 1351 | 7860 | 11211 | | |

Where: Z = Actual Short Tons Moved
X1 = Programmed Flying Hours
Y1 = Programmed Manpower
X2 = Actual Flying Hours
Y2 = Actual Manpower

Suspected Points of Discontinuity:
X1 = None
Y1 = 12000, 12500, 13000
X2 = None
Y2 = 12200

---

*Actual year-end data which was used to determine remaining data. See Chapter II, Data Modification.

## SOUTHERN AREA

| FY-QTR | Z | X1 | Y1 | X2 | Y2 |
|---|---|---|---|---|---|
| 74-2 | 548 | 5736 | 2346 | 2636 | 2437 |
| -3 | 330 | 5856 | 2346 | 3148 | 2536 |
| -4 | 276 | 5856 | 2346 | 2923 | 2636 |
| 75-1 | 364 | 3004 | 2251 | 3363 | 2735 |
| -2 | 286 | 3164 | 2251 | 2552 | 2834 |
| -3 | 335 | 3164 | 2251 | 2277 | 2934 |
| -4 | 343 | 3164 | 2251 | 2410 | 3033* |
| 76-1 | 295 | 2743 | 2168 | 1850 | 2851 |
| -2 | 294 | 2743 | 2168 | 1289 | 2670 |
| -3 | 370 | 2743 | 2168 | 2100 | 2488 |
| -4 | 333 | 2863 | 2164 | 1652 | 2306* |
| 77-T | 340 | 1440 | 2057 | 1548 | 2306 |
| -1 | 388 | 1440 | 2053 | 1733 | 2307 |
| -2 | 304 | 2109 | 2053 | 1705 | 2307 |
| -3 | 370 | 1440 | 2053 | 2626 | 2308 |
| -4 | 207 | 1440 | 2152 | 2280 | 2308* |
| 78-1 | 330 | 1440 | 1979 | | |
| -2 | 320 | 1440 | 1979 | | |

Where: Z = Actual Short Tons Moved
X1 = Programmed Flying Hours
Y1 = Programmed Manpower
X2 = Actual Flying Hours
Y2 = Actual Manpower

Suspected Points of Discontinuity:
X1 = 1500, 4500
Y1 = 2100, 2200, 2300
X2 = None
Y2 = 2400, 2700

---

*Actual year-end data which was used to determine remaining data. See Chapter II, Data Modification.

## NORTHEASTERN AREA

| FY-QTR | Z | X1 | Y1 | X2 | Y2 |
|---|---|---|---|---|---|
| 74-2 | 1720 | 1800 | 4087 | 1697 | 3399 |
| -3 | 1572 | 1800 | 4087 | 1701 | 3231 |
| -4 | 1454 | 1800 | 4087 | 2028 | 3062 |
| 75-1 | 1529 | 1984 | 1965 | 2089 | 2894 |
| -2 | 1705 | 2339 | 1965 | 1708 | 2725 |
| -3 | 1537 | 2339 | 1965 | 1843 | 2557 |
| -4 | 1673 | 2359 | 1965 | 2008 | 2388* |
| 76-1 | 1184 | 2274 | 2050 | 1349 | 2229 |
| -2 | 774 | 2164 | 2050 | 1336 | 2070 |
| -3 | 1002 | 2139 | 2075 | 1363 | 1910 |
| -4 | 1339 | 2274 | 2024 | 1088 | 1751* |
| 77-T | 890 | 1438 | 2083 | 1006 | 1699 |
| -1 | 716 | 1348 | 2083 | 1221 | 1647 |
| -2 | 662 | 1212 | 2083 | 1218 | 1596 |
| -3 | 964 | 1438 | 2083 | 1416 | 1544 |
| -4 | 763 | 1456 | 2083 | 1257 | 1492* |
| 78-1 | 772 | 1420 | 2064 | | |
| -2 | 768 | 1420 | 2038 | | |

Where: Z = Actual Short Tons Moved
X1 = Programmed Flying Hours
Y1 = Programmed Manpower
X2 = Actual Flying Hours
Y2 = Actual Manpower

Suspected Points of Discontinuity:
X1 = 1700, 2000
Y1 = 4000
X2 = 1000, 1600
Y2 = 2000, 2800

---

*Actual year-end data which was used to determine remaining data. See Chapter II, Data Modification.

TOTAL DATA

| FY-QTR | Z | X1 | Y1 | X2 | Y2 |
|---|---|---|---|---|---|
| 74-2 | 26843 | 190709 | 154200 | 132973 | 161467 |
| -3 | 22239 | 183069 | 152050 | 143967 | 159044 |
| -4 | 23512 | 188616 | 151310 | 155511 | 156620 |
| 75-1 | 26399 | 184068 | 142431 | 146495 | 154196 |
| -2 | 23895 | 174914 | 142250 | 134911 | 151771 |
| -3 | 22233 | 176267 | 142319 | 130133 | 149349 |
| -4 | 23905 | 185665 | 142369 | 131089 | 146924* |
| 76-1 | 24102 | 130414 | 141358 | 127206 | 142710 |
| -2 | 19748 | 119099 | 140879 | 98658 | 138498 |
| -3 | 16778 | 114029 | 140873 | 95203 | 134284 |
| -4 | 17123 | 121080 | 133697 | 80516 | 130070* |
| 77-T | 121080 | 124631 | 129889 | 92079 | 129138 |
| -1 | 16569 | 103265 | 128958 | 94785 | 128206 |
| -2 | 15899 | 108466 | 128949 | 100684 | 127273 |
| -3 | 17109 | 109735 | 128765 | 108532 | 126341 |
| -4 | 15452 | 110248 | 129169 | 110659 | 125409* |
| 78-1 | 16904 | 115599 | 123239 | | |
| -2 | 15634 | 120387 | 123213 | | |

Where: Z = Actual Short Tons Moved
X1 = Programmed Flying Hours
Y1 = Programmed Manpower
X2 = Actual Flying Hours
Y2 = Actual Manpower

Suspected Points of Discontinuity:
X1 = 130000, 140000
Y1 = 130000, 140000, 150000
X2 = 127000
Y2 = 140000

---

*Actual year-end data which was used to determine remaining data. See Chapter II, Data Modification.

## APPENDIX E

## DERIVED EQUATIONS BY AREA

## PROGRAMMED

**European:**

$$Z = -16845.49010 + 0.09428X + 0.28292Y - 2050.76151X_{D_1}$$

Where:
$Z$ = Short Tons
$X$ = Flying Hours
$Y$ = Manpower
$X_{D_1} = \begin{cases} 1, & \text{if } X > 66500 \\ 0, & \text{otherwise} \end{cases}$

All remaining variables = 0

**Pacific:**

$$Z = -4391.18216 + 0.55141X - 0.24170Y + 541.44135Y_{D_3}$$
$$- 17285.71810X_{D_1} - 0.35122(X\text{-}70000)X_{P_1} + 3033.02733Y_{D_1}$$

Where:
$Z$ = Short Tons
$X$ = Flying Hours
$Y$ = Manpower
$X_{D_1} = X_{P_1} = \begin{cases} 1, & \text{if } X > 70000 \\ 0, & \text{otherwise} \end{cases}$

$Y_{D_1} = \begin{cases} 1, & \text{if } Y > 49000 \\ 0, & \text{otherwise} \end{cases}$

$Y_{D_3} = \begin{cases} 1, & \text{if } Y > 60000 \\ 0, & \text{otherwise} \end{cases}$

All remaining variables = 0

**Alaskan:**

$$Z = 1774.46948 + 0.12407X - 0.09345Y$$

Where:
$Z$ = Short Tons
$X$ = Flying Hours
$Y$ = Manpower

All remaining variables = 0

**Southern:**

$$Z = 303.97209 + 0.01443X - 0.00532Y$$

Where: $Z$ = Short Tons
$X$ = Flying Hours
$Y$ = Manpower

All remaining variables = 0

**Northeastern:**

$$Z = 12777.38987 + 0.14928X - 5.85725Y + 143.38485(Y-4000)Y_{P_1}$$

Where: $Z$ = Short Tons
$X$ = Flying Hours
$Y$ = Manpower
$Y_{P_1} = \begin{cases} 1, & \text{if } Y > 4000 \\ 0, & \text{otherwise} \end{cases}$

All remaining variables = 0

**Total Data:**

$$Z = 3420.16333 + 0.00365X + 0.09829Y + 5721.21114X_{D_1}$$

Where: $Z$ = Short Tons
$X$ = Flying Hours
$Y$ = Manpower
$X_{D_1} = \begin{cases} 1, & \text{if } X > 130000 \\ 0, & \text{otherwise} \end{cases}$

All remaining variables = 0

## ACTUAL

**European:**

$$Z = 126468.43720 - 0.00941X - 1.71398Y + 3.74566(Y-70000)Y_{P_2}$$

Where: $Z$ = Short Tons
$X$ = Flying Hours
$Y$ = Manpower
$Y_{P_2} = \begin{cases} 1, & \text{if } Y > 70000 \\ 0, & \text{otherwise} \end{cases}$

All remaining variables = 0

Pacific:

$$Z = 11980.50391 - 0.31119X + 0.10060Y + 7648.24262X_{D_2}$$

$$+ 3204.03004X_{D_1} + 2034.87252X_{D_3} + 0.15037(X-51000)X_{P_2}$$

Where:

$Z$ = Short Tons

$X$ = Flying Hours

$Y$ = Manpower

$$X_{D_1} = \begin{cases} 1, & \text{if } X > 36000 \\ 0, & \text{otherwise} \end{cases}$$

$$X_{D_2} = X_{P_2} = \begin{cases} 1, & \text{if } X > 51000 \\ 0, & \text{otherwise} \end{cases}$$

$$X_{D_3} = \begin{cases} 1, & \text{if } X > 70000 \\ 0, & \text{otherwise} \end{cases}$$

All remaining variables = 0

Alaskan:

$$Z = -2051.00354 + 0.01744X + 0.34045Y - 486.92236Y_{D_1}$$

Where:

$Z$ = Short Tons

$X$ = Flying Hours

$Y$ = Manpower

$$Y_{D_1} = \begin{cases} 1, & \text{if } Y > 12200 \\ 0, & \text{otherwise} \end{cases}$$

All remaining variables = 0

Southern:

$$Z = 417.60027 + 0.02530X - 0.05395Y$$

Where:

$Z$ = Short Tons

$X$ = Flying Hours

$Y$ = Manpower

All remaining variables = 0

Northeastern:

$$Z = -1509.42140 + 2.38735X + 0.07210Y - 870.50057X_{D_1} - 2.59719(X-1600)X_{P_2}$$

Where:
$Z$ = Short Tons
$X$ = Flying Hours
$Y$ = Manpower
$$X_{D_1} = \begin{cases} 1, & \text{if } X > 1100 \\ 0, & \text{otherwise} \end{cases}$$

$$X_{P_2} = \begin{cases} 1, & \text{if } X > 1600 \\ 0, & \text{otherwise} \end{cases}$$

All remaining variables = 0

Total Data:

$$Z = 1325.18607 - 0.02762X + 0.14046Y + 5165.17698X_{D_1}$$

Where:
$Z$ = Short Tons
$X$ = Flying Hours
$Y$ = Manpower
$$X_{D_1} = \begin{cases} 1, & \text{if } X > 127000 \\ 0, & \text{otherwise} \end{cases}$$

All remaining variables = 0

# APPENDIX F

# RESIDUALS BY AREA BY QUARTER

## EUROPEAN

| | | Actual | | Programmed | |
|---|---|---|---|---|---|
| FY-QTR | $Z$ | $\hat{Z}$ | $Z-\hat{Z}$ | $\hat{Z}$ | $Z-\hat{Z}$ |
| 75-2 | 8877 | 7054 | 1823 | 8743 | 134 |
| -3 | 7701 | 6976 | 725 | 8829 | -1128 |
| -4 | 7479 | 6888 | 591 | 7596 | - 117 |
| 76-1 | 7876 | 9696 | -1820 | 6620 | 1274 |
| -2 | 7522 | 9726 | -2204 | 7891 | - 369 |
| -3 | 6576 | 9722 | -3146 | 7903 | -1327 |
| -4 | 5650 | 9697 | -4047 | 6592 | - 942 |
| 77-T | 6469 | 10948 | -4479 | 6755 | - 286 |
| -1 | 8003 | 11047 | -3044 | 7327 | 676 |
| -2 | 7652 | 11053 | -3401 | 7424 | 228 |
| -3 | 8122 | 11197 | -3075 | 7781 | 341 |
| -4 | 7940 | 11221 | -3281 | 7700 | 240 |
| 78-1 | 8680 | 11951 | -3260 | 8112 | 568 |
| -2 | 7563 | 11940 | -4377 | 6176 | 1387 |
| 14 | | | -32995 | | 679 |

## PACIFIC

| FY-QTR | Z | Actual $\hat{Z}$ | Actual $Z-\hat{Z}$ | Programmed $\hat{Z}$ | Programmed $Z-\hat{Z}$ |
|---|---|---|---|---|---|
| 75-2 | 10872 | 7731 | 3141 | 11209 | - 337 |
| -3 | 10529 | 7691 | 2838 | 11259 | - 730 |
| -4 | 12250 | 7692 | 4558 | 11256 | 994 |
| 76-1 | 12437 | 5962 | 5475 | 11350 | 1087 |
| -2 | 9185 | 6653 | 2532 | 10160 | - 975 |
| -3 | 7114 | 8324 | -1210 | 7202 | - 88 |
| -4 | 8007 | 8107 | - 100 | 8031 | - 24 |
| 77-T | 6593 | 7152 | - 559 | 6853 | - 260 |
| -1 | 5670 | 8303 | -2633 | 4873 | 797 |
| -2 | 5629 | 7581 | -1952 | 6153 | - 524 |
| -3 | 5977 | 8155 | -2178 | 5141 | 836 |
| -4 | 4829 | 7837 | -3008 | 5678 | - 849 |
| 78-1 | 5350 | 7235 | -1885 | 7059 | -1709 |
| -2 | 5632 | 6557 | - 925 | 8262 | -2630 |
| 14 | | | 4094 | | -4412 |

## ALASKAN

| | | Actual | | Programmed | |
|---|---|---|---|---|---|
| FY-QTR | Z | $\hat{Z}$ | $Z-\hat{Z}$ | $\hat{Z}$ | $Z-\hat{Z}$ |
| 75-2 | 2155 | 2015 | 140 | 2091 | 64 |
| -3 | 2131 | 2031 | 100 | 2127 | 4 |
| -4 | 2160 | 2051 | 109 | 2213 | - 53 |
| 76-1 | 2310 | 2243 | 67 | 1901 | 409 |
| -2 | 1973 | 2247 | -274 | 1817 | 156 |
| -3 | 1716 | 2250 | -534 | 1843 | -127 |
| -4 | 1794 | 2230 | -436 | 1904 | -110 |
| 77-T | 2023 | 2075 | - 52 | 1894 | 129 |
| -1 | 1792 | 2047 | -255 | 1708 | 84 |
| -2 | 1652 | 2070 | -418 | 1869 | -217 |
| -3 | 1676 | 2059 | -383 | 1804 | -128 |
| -4 | 1713 | 2062 | -349 | 1825 | -122 |
| 78-1 | 1772 | 1914 | -142 | 1779 | - 7 |
| -2 | 1351 | 1938 | -578 | 1950 | -599 |
| 14 | | | -3014 | | -507 |

SOUTHERN

| | | Actual | | Programmed | |
|---|---|---|---|---|---|
| FY-QTR | $Z$ | $\hat{Z}$ | $Z-\hat{Z}$ | $\hat{Z}$ | $Z-\hat{Z}$ |
| 75-2 | 286 | 376 | -90 | 338 | -52 |
| -3 | 335 | 376 | -41 | 338 | - 3 |
| -4 | 343 | 376 | -33 | 338 | 5 |
| 76-1 | 295 | 370 | -75 | 332 | -37 |
| -2 | 294 | 370 | -76 | 332 | -38 |
| -3 | 370 | 370 | 0 | 332 | 38 |
| -4 | 333 | 373 | -40 | 334 | - 1 |
| 77-T | 340 | 343 | - 3 | 314 | 26 |
| -1 | 388 | 343 | 45 | 314 | 74 |
| -2 | 304 | 360 | -56 | 323 | -20 |
| -3 | 370 | 343 | 27 | 314 | 56 |
| -4 | 207 | 343 | -136 | 314 | -107 |
| 78-1 | 330 | 347 | -17 | 314 | 16 |
| -2 | 320 | 347 | -27 | 314 | 6 |
| 14 | | | -522 | | -37 |

## NORTHEASTERN

| FY-QTR | Z | Actual $\hat{Z}$ | Actual $Z-\hat{Z}$ | Programmed $\hat{Z}$ | Programmed $Z-\hat{Z}$ |
|---|---|---|---|---|---|
| 75-2 | 1705 | 1426 | 279 | 1617 | 88 |
| -3 | 1537 | 1426 | 111 | 1617 | - 80 |
| -4 | 1673 | 1422 | 251 | 1620 | 53 |
| 76-1 | 1184 | 1462 | -278 | 1109 | 75 |
| -2 | 774 | 1469 | -695 | 1093 | -319 |
| -3 | 1002 | 1476 | -474 | 943 | 59 |
| -4 | 1339 | 1444 | -105 | 1262 | 77 |
| 77-T | 890 | 1203 | -313 | 791 | 99 |
| -1 | 716 | 988 | -272 | 778 | - 62 |
| -2 | 662 | 664 | - 2 | 758 | - 96 |
| -3 | 964 | 1203 | -239 | 791 | 173 |
| -4 | 763 | 1246 | -483 | 794 | - 31 |
| 78-1 | 772 | 1159 | -387 | 900 | -128 |
| -2 | 768 | 1157 | -389 | 1052 | -285 |
| 14 | | | -2996 | | -376 |

## TOTAL DATA

| | | Actual | | Programmed | |
|---|---|---|---|---|---|
| FY-QTR | $Z$ | $\hat{Z}$ | $Z-\hat{Z}$ | $\hat{Z}$ | $Z-\hat{Z}$ |
| 75-2 | 23895 | 19982 | 3913 | 23762 | 133 |
| -3 | 22233 | 19955 | 2278 | 23774 | -1541 |
| -4 | 23905 | 19702 | 4203 | 23813 | 92 |
| 76-1 | 24102 | 21086 | 3016 | 23512 | 590 |
| -2 | 19748 | 17824 | 1924 | 17703 | 2045 |
| -3 | 16778 | 17963 | -1185 | 17683 | - 905 |
| -4 | 17123 | 16760 | 363 | 17004 | 119 |
| 77-T | 16315 | 16127 | 188 | 16642 | - 327 |
| -1 | 16559 | 16586 | - 27 | 16473 | 96 |
| -2 | 15899 | 16441 | -542 | 16491 | - 592 |
| -3 | 17109 | 16381 | 728 | 16478 | 631 |
| -4 | 15452 | 16423 | -971 | 16519 | -1067 |
| 78-1 | 16904 | 15442 | 1462 | 15955 | 949 |
| -2 | 15634 | 15307 | 327 | 15970 | - 336 |
| 14 | | | 15677 | | - 113 |

APPENDIX G

SPSS PROGRAM

```
ØØ1Ø##S,R(SL) :,8,16;;,16
ØØ2Ø$:IDENT:WP1149,AFIT/LSG  LAMB/SARNACKI THESIS LSSR 21-78B
ØØ3Ø$:SELECT:SPSS/SPSS
ØØ4ØRUN NAME;SDT DLR PROGRAM
ØØ5ØVARIABLE LIST;Z,X,Y
ØØ6ØINPUT FORMAT;FREEFIELD
ØØ7ØN OF CASES;16
ØØ8ØINPUT MEDIUM;CARD
ØØ9ØVAR LABELS;Z,ACTUAL SHORT TONS/
Ø1ØØ;X,PROGRAMMED FLYING HOURS/
Ø11Ø;Y,PROGRAMMED MANPOWER
Ø12ØIF;(X GT 13ØØØØ) XD1=1
Ø13ØIF;(X GT 13ØØØØ) XP1=X-13ØØØØ
Ø14ØIF;(X GT 14ØØØØ) XD2=1
Ø15ØIF;(X GT 14ØØØØ) XP2=X-14ØØØØ
Ø16ØIF;(Y GT 13ØØØØ) YD1=1
Ø17ØIF;(Y GT 13ØØØØ) YP1=Y-13ØØØØ
Ø18ØIF;(Y GT 14ØØØØ) YD2=1
Ø19ØIF;(Y GT 14ØØØØ) YP2=Y-14ØØØØ
Ø2ØØIF;(Y GT 15ØØØØ) YD3=1
Ø21ØIF;(Y GT 15ØØØØ) YP3=Y-15ØØØØ
Ø22ØREGRESSION;VARIABLES=Z,X,Y,XD1 TO YP3/
Ø23Ø;REGRESSION=Z(2Ø,2.5) WITH X(6),Y(4),XD1 TO YP(3) RESID=Ø
Ø24ØSTATISTICS;1,2,4,5,6
Ø25ØREAD INPUT DATA
Ø26Ø$:SELECTA:SDTDATA
Ø27ØSCATTERGRAM:Z WITH X,Y
Ø28ØSTATISTICS;ALL
Ø29ØFINISH
Ø3ØØ$:END JOB
```

Note: In line 0230, the F inclusion level option was used. If the dummy variable's entering F value is not greater than 2.5 ($\alpha$=0.10), the dummy variable is not included in the regression equation (16:346).

APPENDIX H

FORTRAN PROGRAM

```
ØØ1ØC SECOND DESTINATION TRANSPORTATION BUDGET COMPUTATION PROGRAM
ØØ2ØC
ØØ3Ø IMPLICIT INTEGER (A,E,F,P,S,X,Y)
ØØ4Ø INTEGER Z
ØØ5Ø DIMENSION M(6,5,2)
ØØ6Ø PRINT," TYPE IN THE SLOPE VALUES OF THE FOLLOWING VARIABLES:"
ØØ7Ø PRINT," NOTE:  TYPE IN A Ø. FOR VARIABLES NOT IN THE EQUATION!"
ØØ8Ø PRINT," CONST X Y XD1 XP1 XD2 XP2 YD1 YP1 YD2 YP2 YD3 YP3"
ØØ9Ø READ,CONST,BX,BY,BXD1,BXP1,BXD2,BXP2,BYD1,BYP1,BYD2,BYP2,BYD3,BYP3
Ø1ØØ PRINT, " "
Ø11Ø PRINT," TYPE IN THE COSTS TO SHIP ONE TON IN THE FOLLOWING ORDER:"
Ø12Ø PRINT," PACIFIC(P) ALASKA(A) NORTHEAST(N) EUROPE(E) SOUTHERN(S)"
Ø13Ø READ,PC,AC,NC,EC,SC
Ø14Ø PRINT," "
Ø15Ø 1Ø PRINT," TYPE IN THE FISCAL YEAR FOR THIS FORECAST"
Ø16Ø READ,FY
Ø17Ø PRINT," "
Ø18Ø PRINT," TYPE IN THE PROGRAMMED FLYING HOURS(FH) AND MANPOWER(M)"
Ø19Ø PRINT," BY QUARTER IN THE FOLLOWING ORDER:"
Ø2ØØ PRINT," PFH PM AFH AM NFH NM EFH EM SFH SM"
Ø21Ø DO 2Ø J=1,4
Ø2ØØ WRITE (6,1ØØ) J
Ø23Ø 1ØØ FORMAT (/,1X,"TYPE IN THE DATA FOR QUARTER ",I1)
Ø24Ø READ,PFH,PM,AFH,AM,NFH,NM,EFH,EM,SFH,SM
Ø25Ø X=PFH+AFH+NFH+EFH+SFH
Ø26Ø Y=PM+AM+NM+EM+SM
Ø27Ø XD1=Ø
Ø28Ø XD2=Ø
Ø29Ø YD1=Ø
Ø3ØØ YD2=Ø
Ø31Ø YD3=Ø
Ø32Ø IF (X.GT.13ØØØØ) XD1=1
Ø3ØØ XP1=XD1
Ø34Ø IF (X.GT.14ØØØØ) XD2=1
Ø35Ø XP2=XD2
```

```
0360 IF (Y.GT.130000) YD1=1
0370 YP1=YD1
0380 IF (Y.GT.140000) YD2=1
0390 YP2=YD2
0400 IF (Y.GT.150000) YD3=1
0410 YP3=YD3
0420 Z1=CONST+BX*X+BY*Y+BXD1*XD1+BXP1*(X-130000)*XP1
0430 Z2=BXD2*XD2+BXP2*(X-140000)*XP2+BYD1*YD1+BYP1*(Y-130000)*YP1
0440 Z3=BYD2*YD2+BYP2*(Y-140000)*YP2+BYD3*YD3+BYP3*(Y-150000)*YP3
0450 Z=Z1+Z2+Z3+0.5
0460 M(1,J,1)=(1.0*PFH/X+1.0*PM/Y)*(Z/2.0)+0.5
0470 M(1,J,2)=M(1,J,1)*PC
0480 M(2,J,1)=(1.0*AFH/X+1.0*AM/Y)*(Z/2.0)+0.5
0490 M(2,J,2)=M(2,J,1)*AC
0500 M(3,J,1)=(1.0*NFH/X+1.0*NM/Y)*(Z/2.0)+0.5
0510 M(3,J,2)=M(3,J,1)*NC
0520 M(4,J,1)=(1.0*EFH/X+1.0*EM/Y)*(Z/2.0)+0.5
0530 M(4,J,2)=M(4,J,1)*EC
0540 M(5,J,1)=(1.0*SFH/X+1.0*SM/Y)*(Z/2.0)+0.5
0550 M(5,J,2)=M(5,J,1)*SC
0560 M(6,J,1)=Z
0570 DO 30 I=1,5
0580 M(6,J,2)=M(6,J,2)+M(I,J,2)
0590 30 CONTINUE
0600 DO 40 K=1,2
0610 DO 50 I=1,6
0620 M(I,5,K)=M(I,5,K)+M(I,J,K)
0630 50 CONTINUE
0640 40 CONTINUE
0650 20 CONTINUE
0660 WRITE (6,110) FY,(((M(I,J,K),J=1,5),I=1,6),K=1,2)
0670 110 FORMAT (//////,14X,"SDT FORECAST FOR FISCAL YEAR ",I4,////,
0680&15X,"TONNAGE ESTIMATES IN SHORT TONS",///,
0690&15X,"Q     U     A     R     T     E     R",/,
0700&3X,"AREA",8X,"1",9X,"2",9X,"3",9X,"4",7X,"TOTAL",//,
```

```
Ø71Ø&1X,"PACIFIC",5I1Ø,//,1X,"ALASKA ",5I1Ø,//,
Ø72Ø&1X,"NORTHEAST",I8,4I1Ø,//,1X,"EUROPE ",5I1Ø,//,
Ø73Ø&1X,"SOUTHERN",I9,4I1Ø,//,3X,"TOTAL",5I1Ø,///,
Ø74Ø&17X,"BUDGET ESTIMATES IN DOLLARS",///,
Ø75Ø&15X,"Q    U    A    R    T    E    R",/,
Ø76Ø&3X,"AREA",8X,"1",9X,"2",9X,"3",9X,"4",7X,"TOTAL",//,
Ø77Ø&1X,"PACIFIC  ",5I1Ø,//,1X,"ALASKA   ",5I1Ø,//,
Ø78Ø&1X,"NORTHEAST",5I1Ø,//,1X,"EUROPE   ",5I1Ø,//,
Ø79Ø&1X,"SOUTHERN ",5I1Ø,//,3X,"TOTAL  ",5I1Ø,//////)
Ø8ØØ PRINT," IF YOU WISH TO MAKE ANOTHER FORECAST WITH THE SAME SLOPES"
Ø81Ø PRINT,"AND COSTS, TYPE IN A 1; OTHERWISE, TYPE IN A Ø!"
Ø82Ø READ,L
Ø83Ø IF (L.NE.1) GO TO 7Ø
Ø84Ø DO 6Ø I=1,6
Ø85Ø DO 6Ø J=1,5
Ø86Ø DO 6Ø K=1,2
Ø87Ø M(I,J,K)=Ø
Ø88Ø 6Ø CONTINUE
Ø89Ø GO TO 1Ø
Ø9ØØ 7Ø STOP
Ø91Ø END
```

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